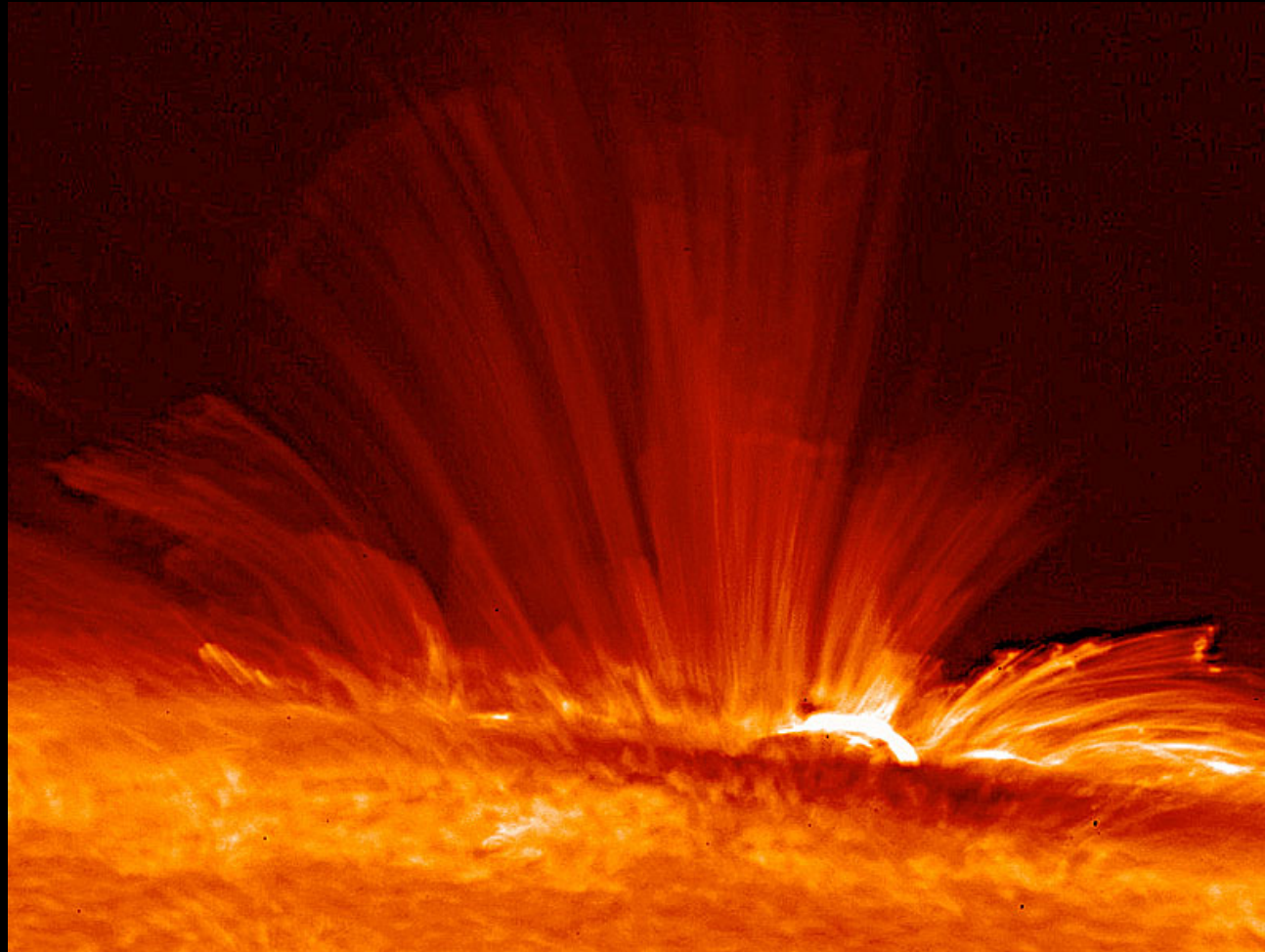


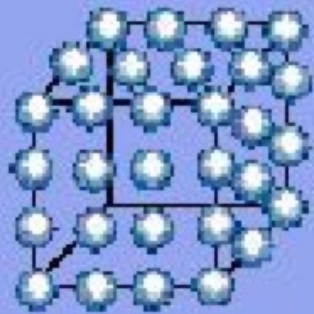
Plasmas



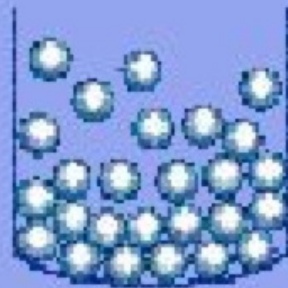
Alex Friedman

This work was performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract Number W-7405-Eng-48.
It is LLNL Report Number UCRL-PRES-23098, and may be obtained in Powerpoint form at: <http://hifweb.llnl.gov/public/slides/Friedman-Plasma-Grades3-5-rev3.ppt>
... or in PDF (Adobe Acrobat) form at: <http://hifweb.llnl.gov/public/slides/Friedman-Plasma-Grades3-5-rev3.pdf>

Plasma is the 4th state of matter



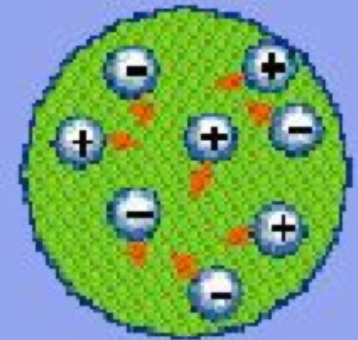
Cold
Solid: Ice



Warm
Liquid: Water

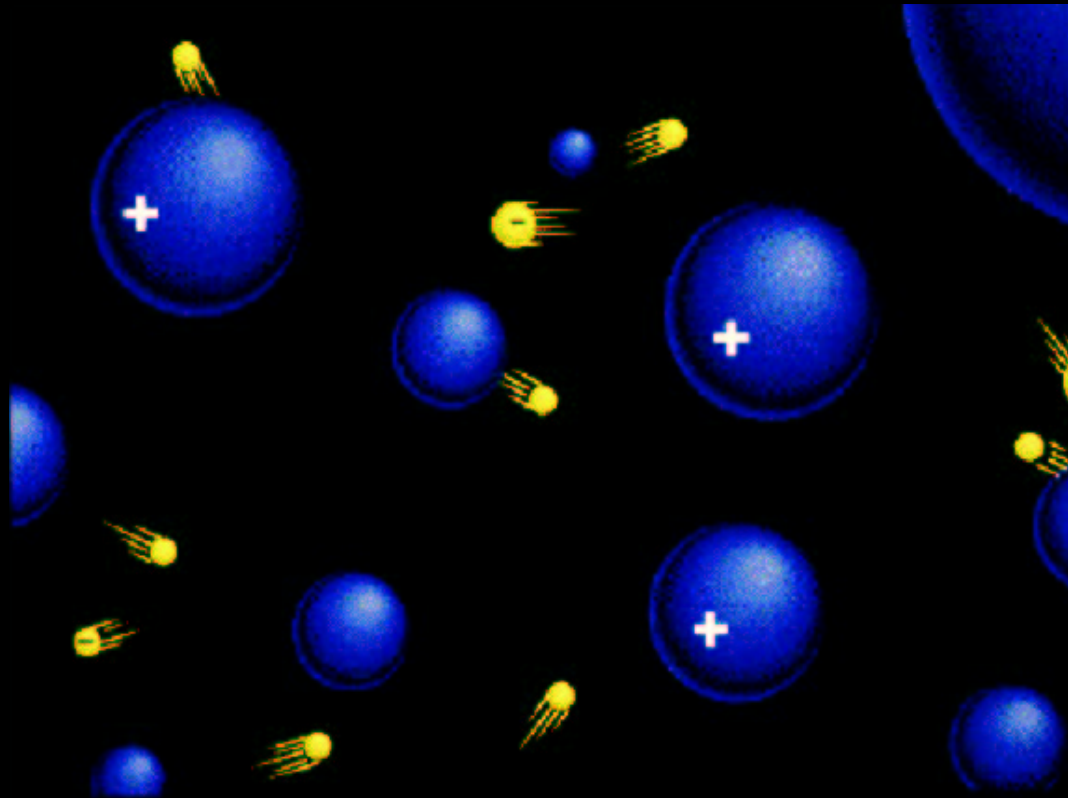


Hot
Gas: Steam



Hotter
Plasma

A plasma is a collection of charged particles



- charge = electrons

+ charge = ions = atoms whose electrons have been ripped off

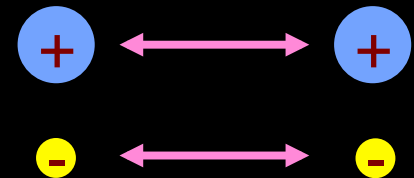
Plasmas behave differently than gases

In a **regular gas**, the atoms move in straight lines until they bang into each other.

In a **plasma**, the ions and electrons push and pull on each other all the time.

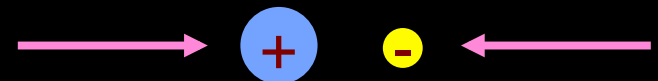
Particles with the same charge repel each other.

Electrons push other electrons away,
and ions push other ions away.



Particles with opposite charges are attracted to each other.

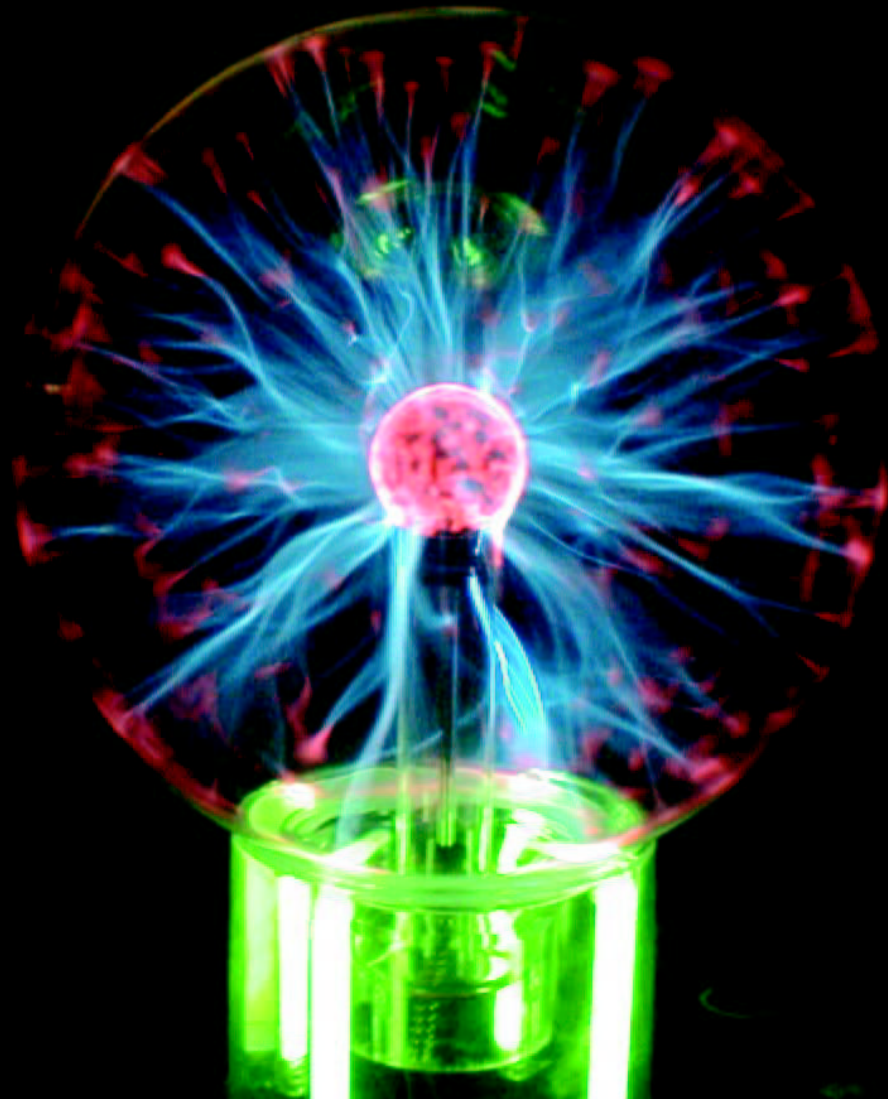
Ions pull on electrons,
and electrons pull on ions.



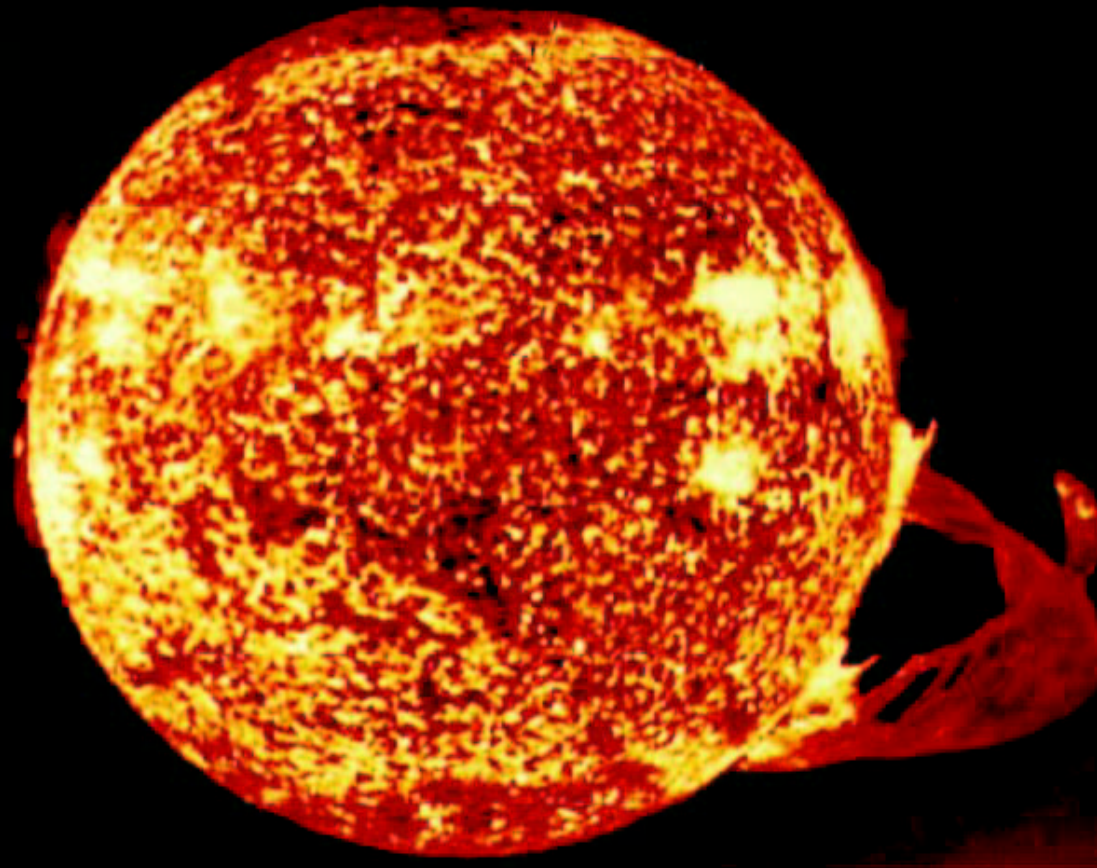
Plasma balls contain helium, neon, argon, and other gases.

When the power is switched on, some of the gas atoms have their electrons ripped from them.

This produces a plasma.



The sun is a plasma, burning with fusion “fire”

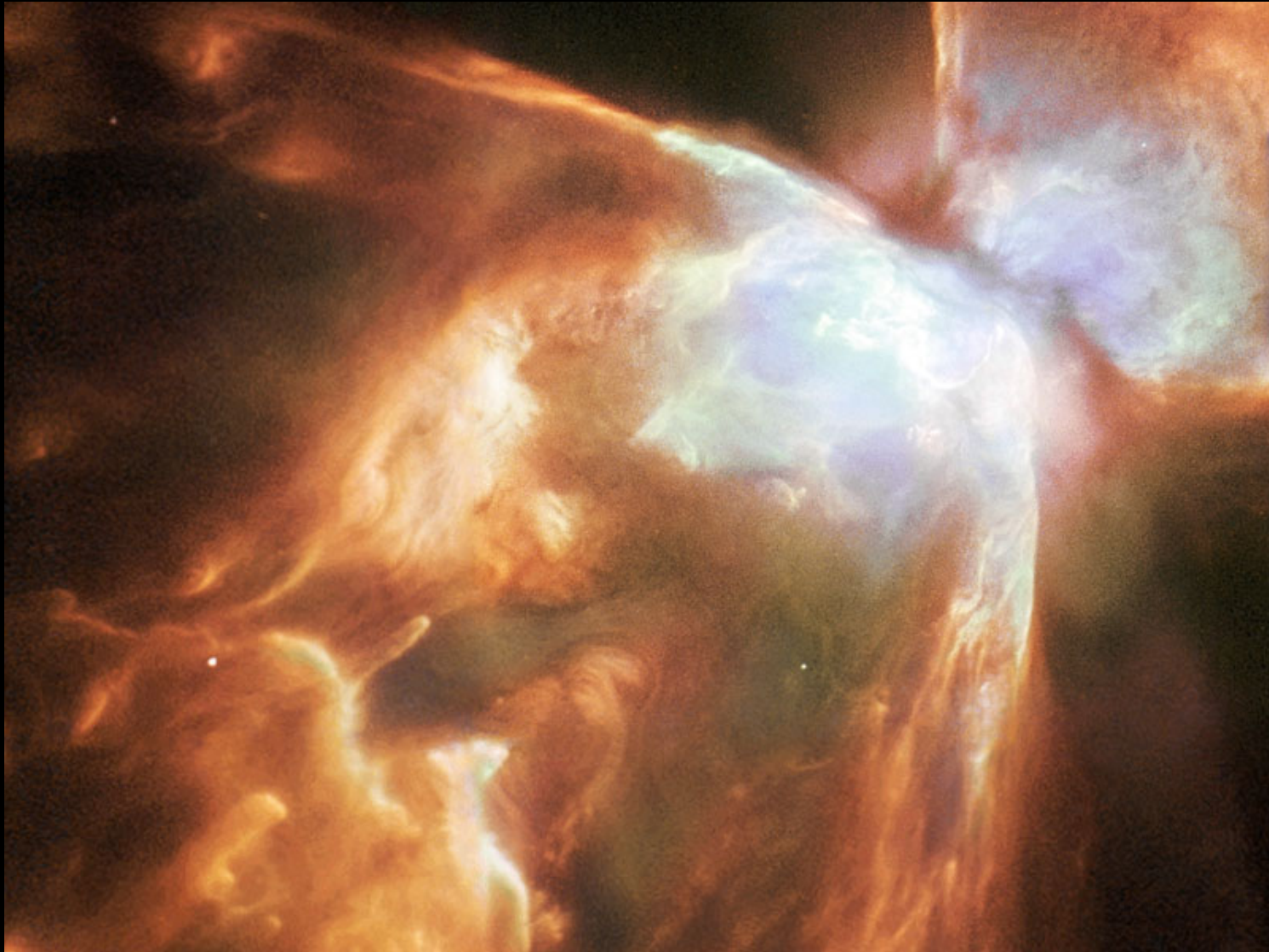


Plasma fills the universe



Catseye Nebula

Bug nebula



Carina nebula



Rosette nebula



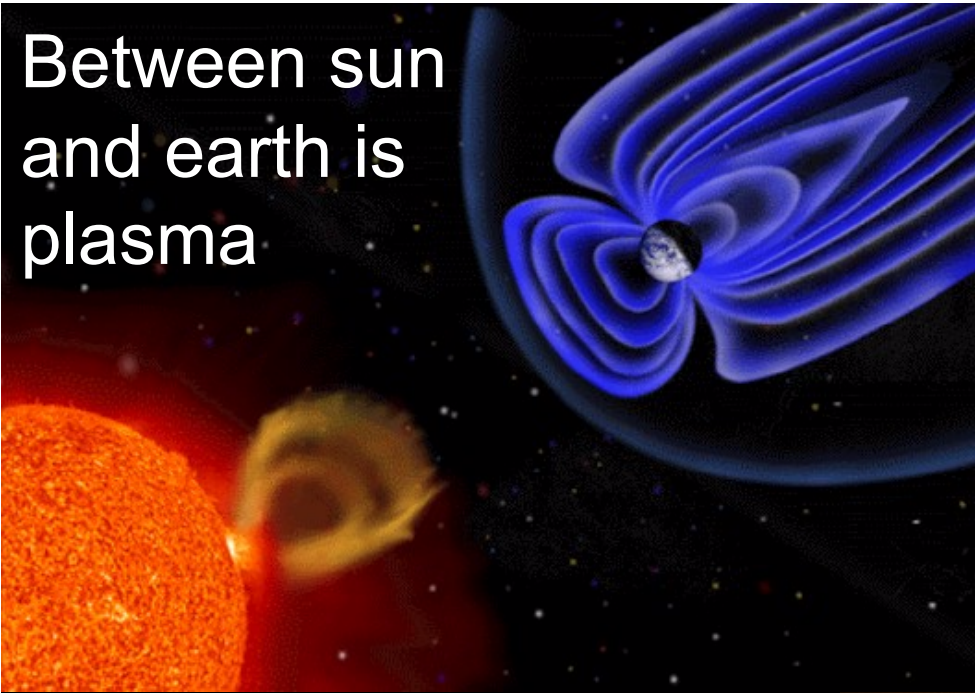
Thor's helmet



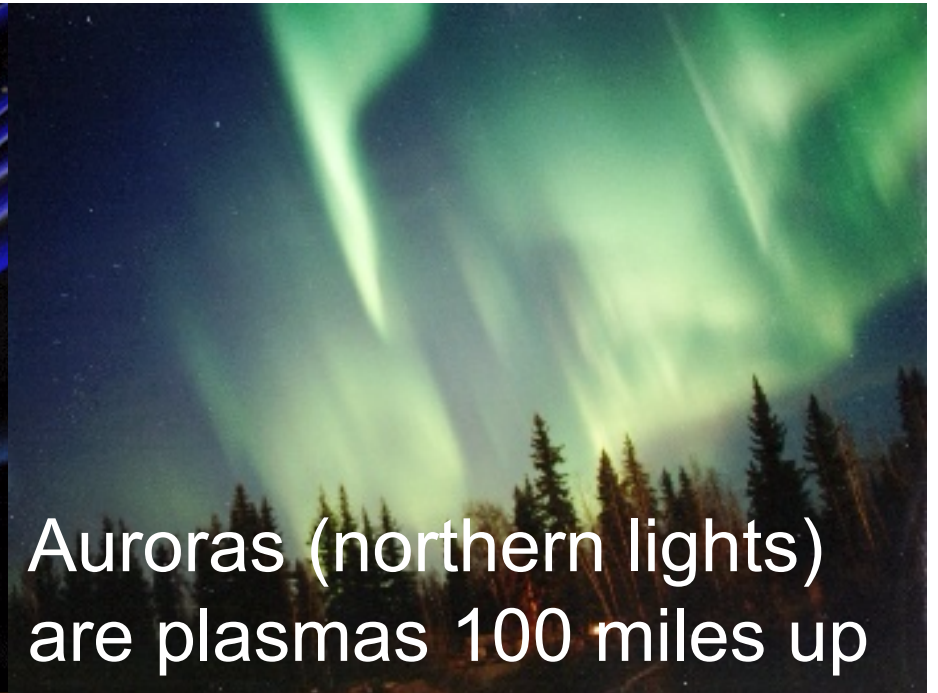
Fireworks and a comet and lightning, all at once!



Between sun
and earth is
plasma

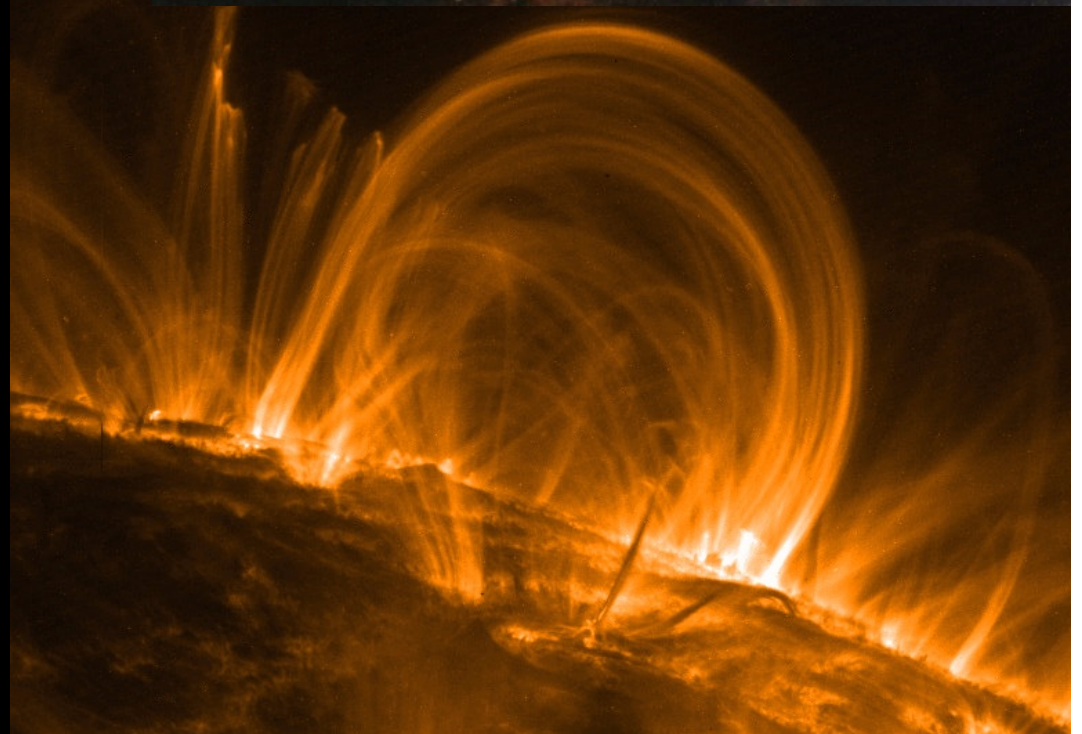


Auroras (northern lights)
are plasmas 100 miles up

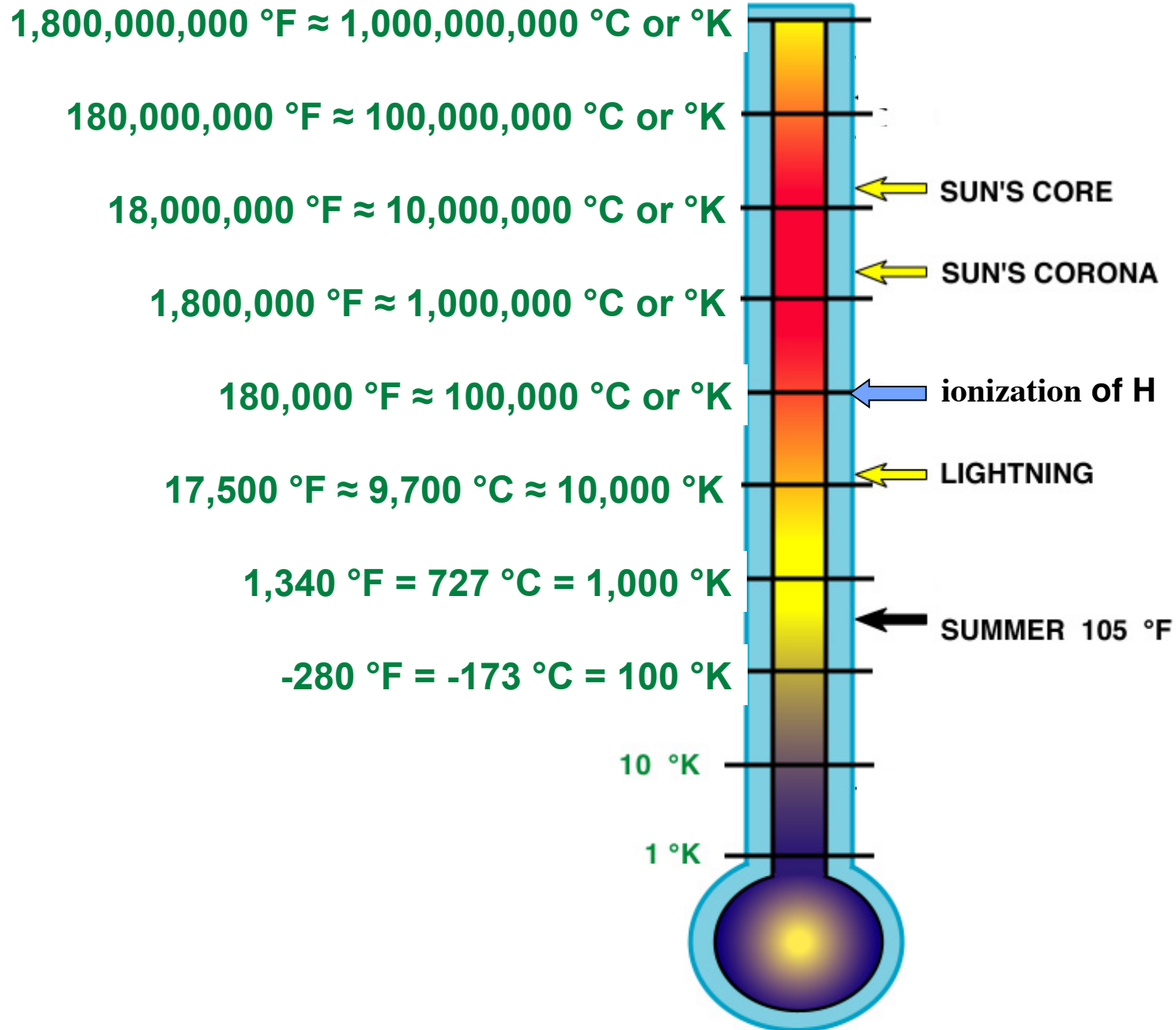


Plasmas respond
to electric and
magnetic forces

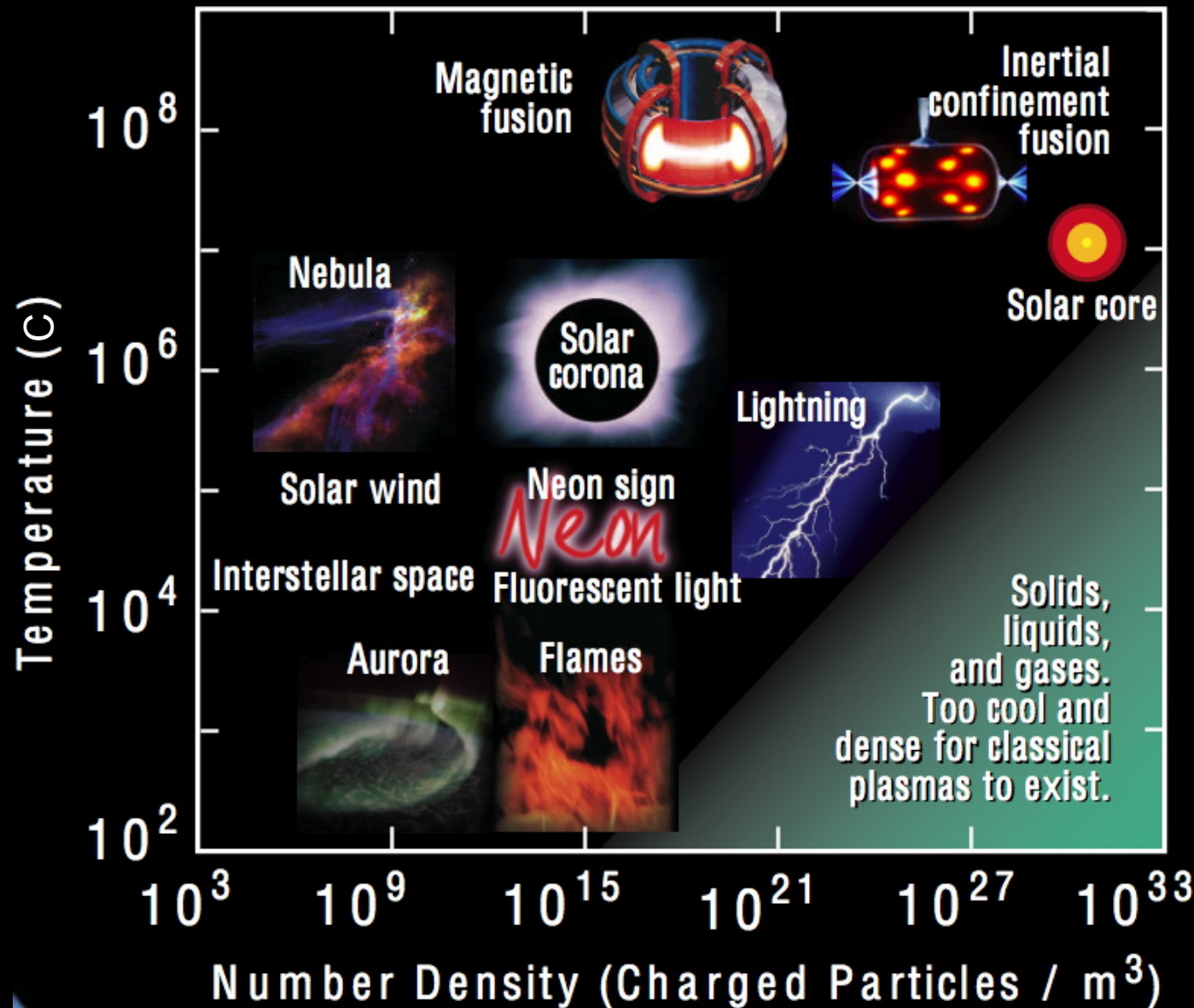
(this is a solar
prominence)



PLASMA THERMOMETER

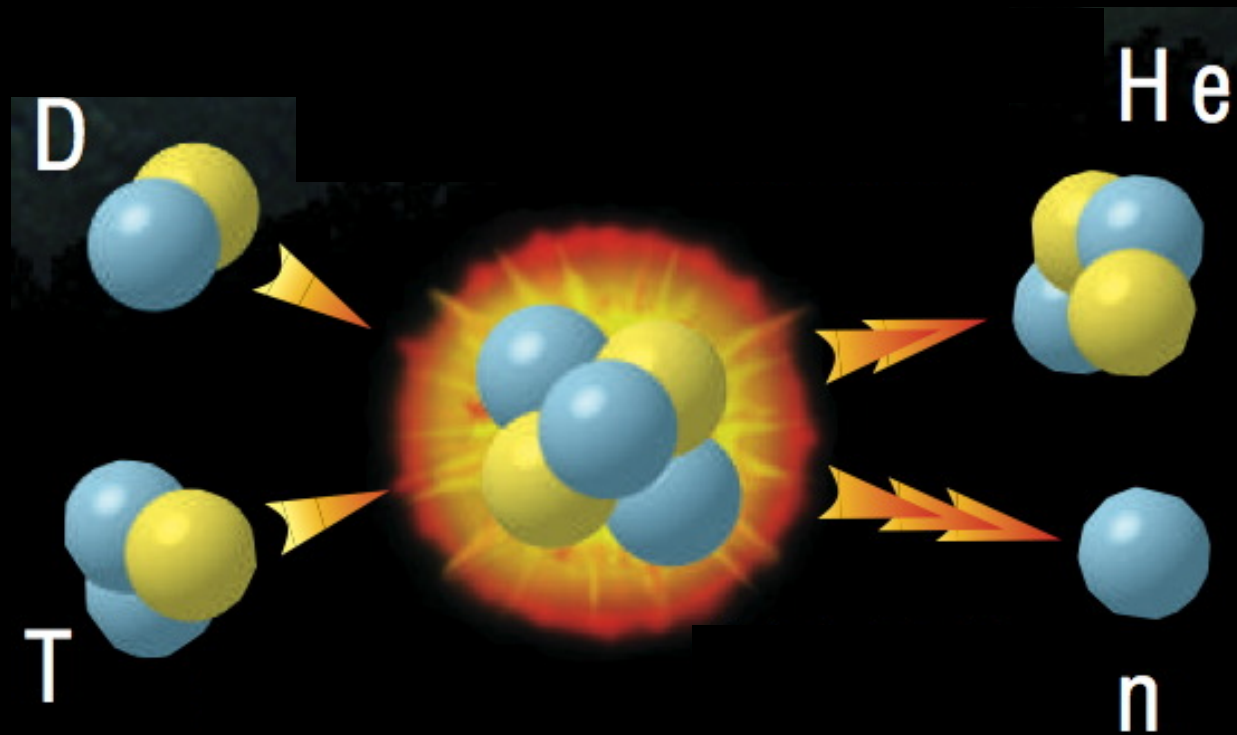


Matter is in the plasma state when it is hot enough, and not too tightly packed

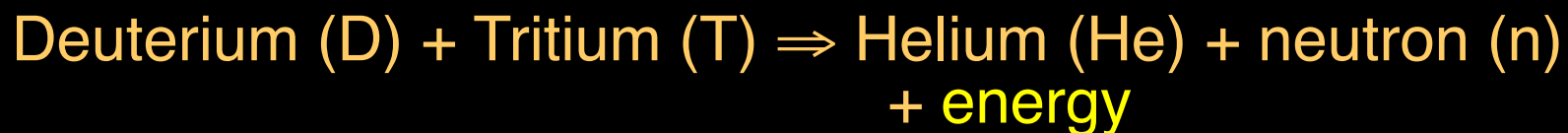


“scientific notation” uses 10^{33} to mean 10 followed by 33 zeros

Fusion occurs when light ions are joined together to make a heavier ion. This releases energy.



Fusion power plants will “fuse” two kinds of Hydrogen ...



To fuse, the ions have to be hot enough (moving fast enough); they are a plasma

To make a lot of energy, this plasma must be kept together long enough for a lot of it to burn

Gravity



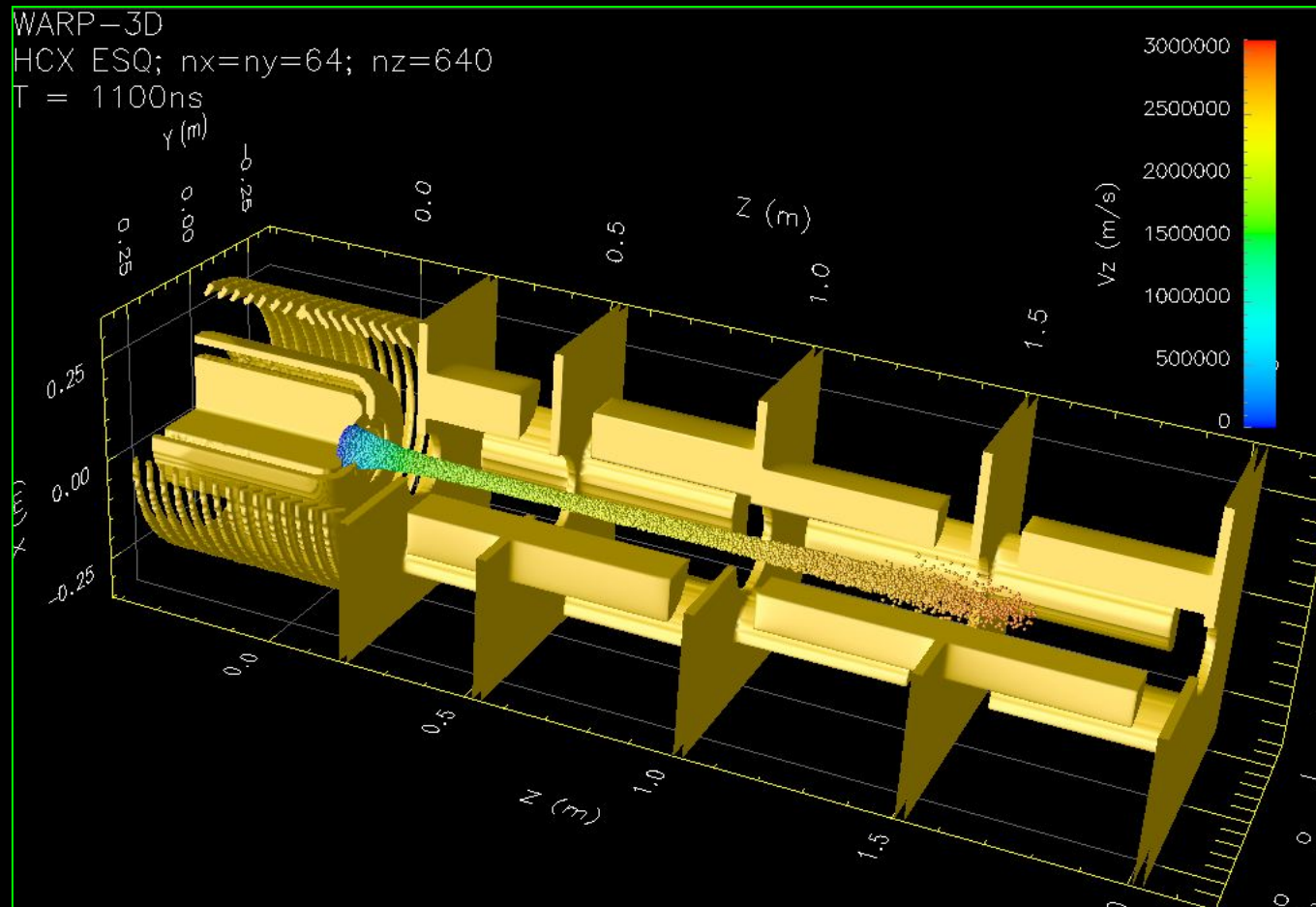
Magnetic Fields



Inertia

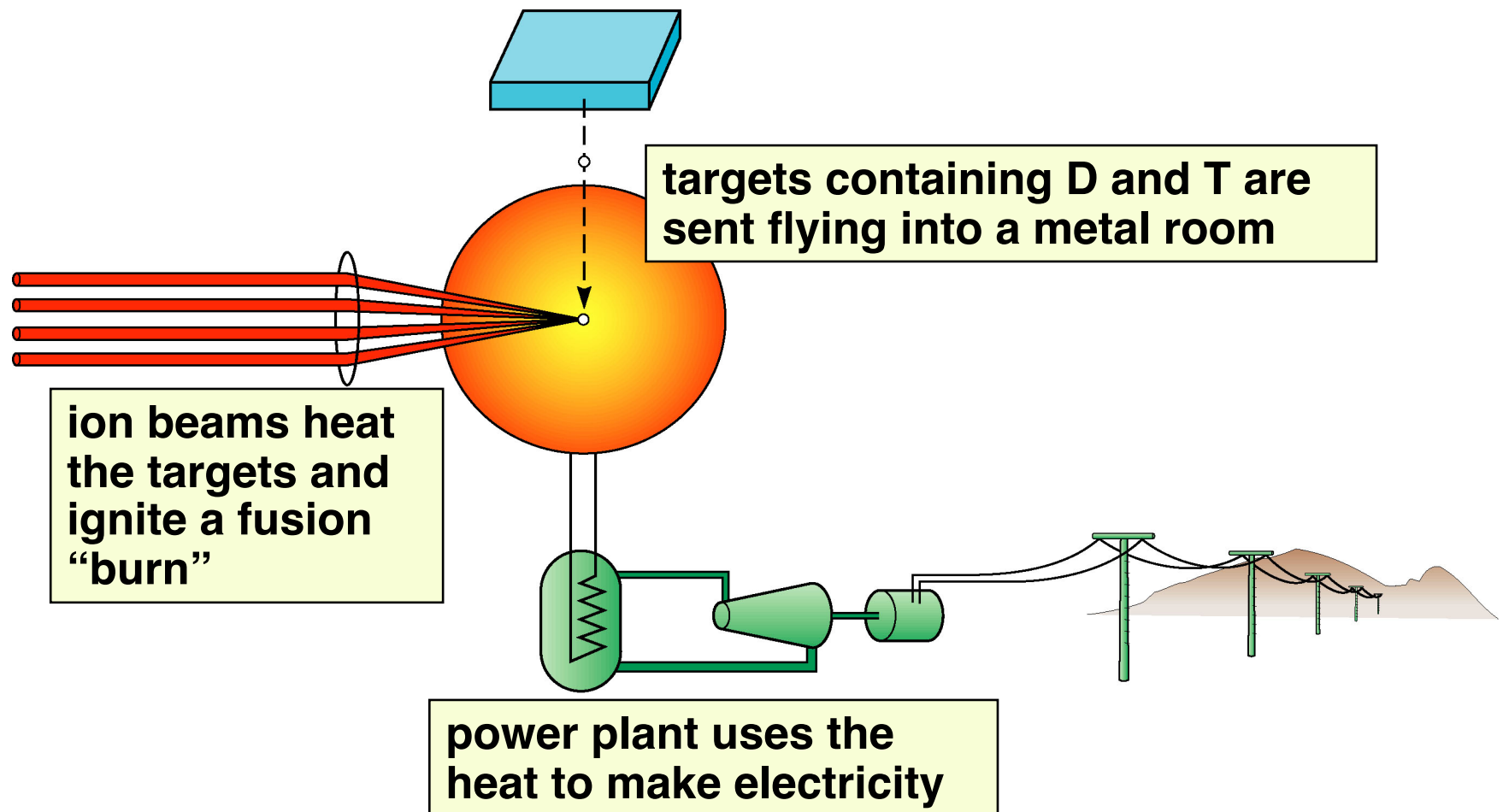


“Beams” of ions are plasmas, too



They are “non-neutral plasmas” because they contain only a few electrons.
But - sometimes too many electrons sneak in and cause trouble!

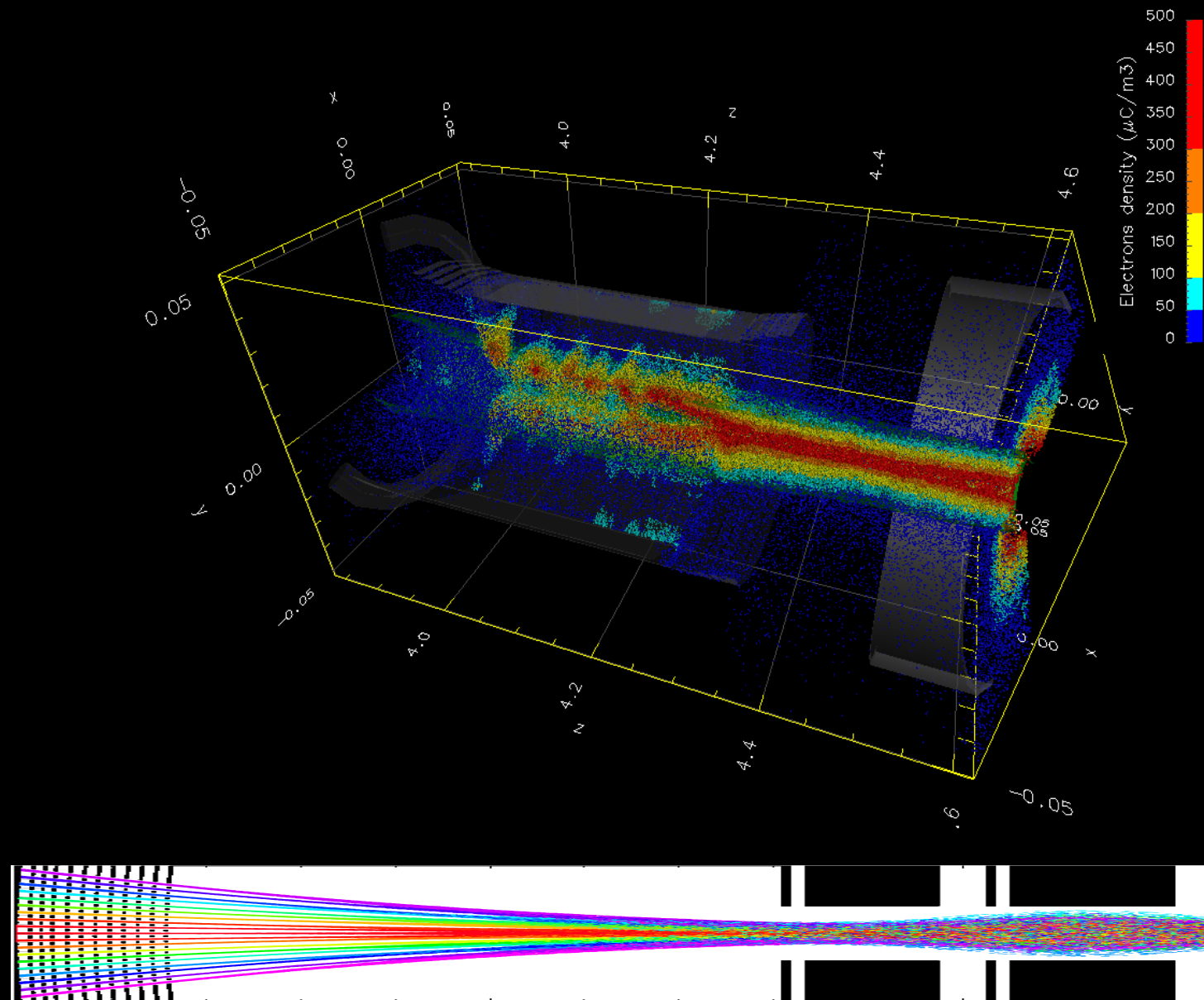
We are trying to use beams of heavy ions to create small fusion fires (little stars), one after the other



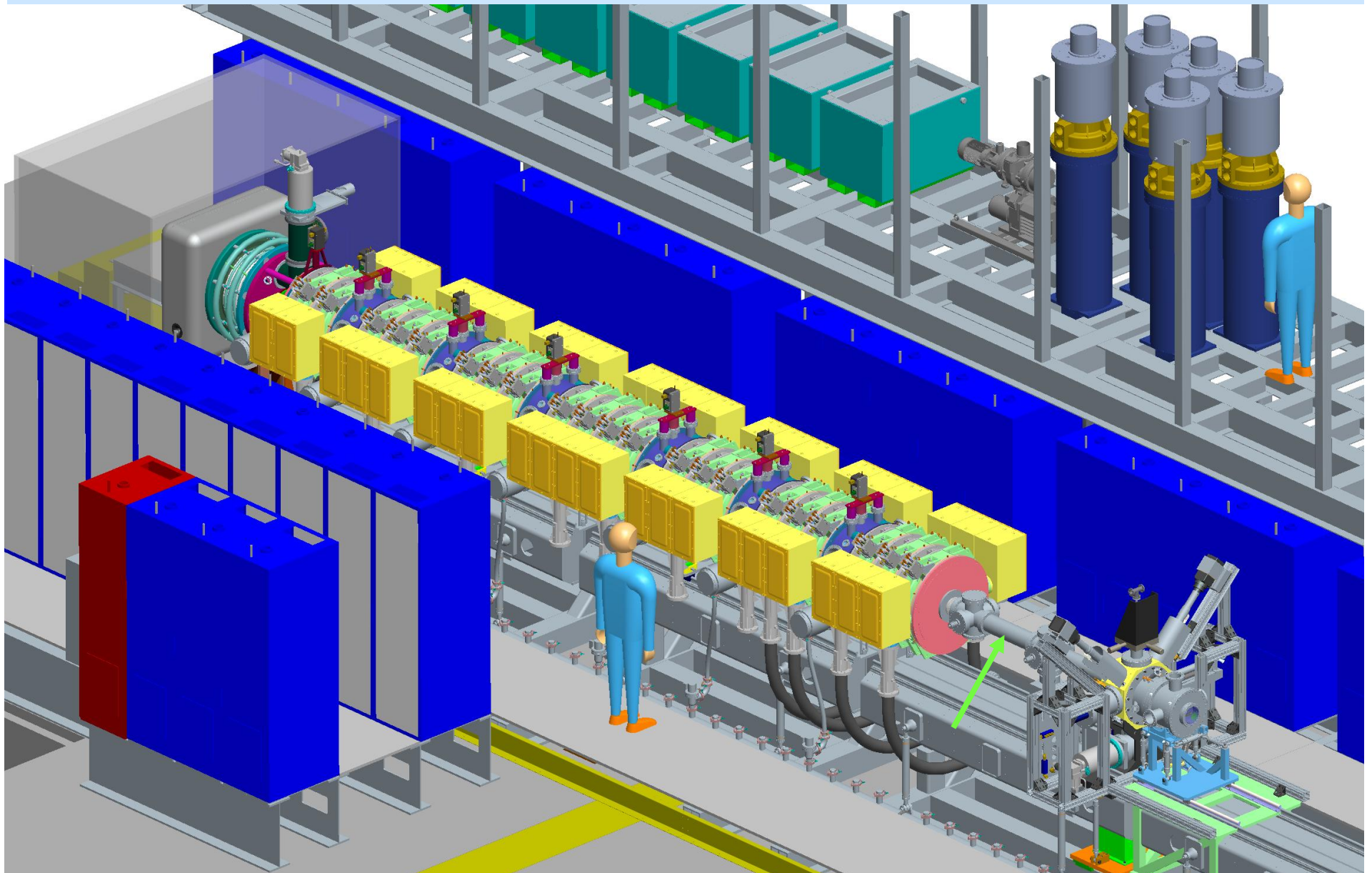
In our experiments, we're studying how ion beams behave, and how they heat matter



My group uses computer simulations to study ion beams



We are building a new ion beam accelerator, called NDCX-II



The Heavy Ion Fusion Science Virtual National Laboratory



NDCX-II as it may appear in action



The Heavy Ion Fusion Science Virtual National Laboratory



We have talked about several things

- **Plasmas** - collections of charged particles whizzing around while pushing and pulling on each other
- **Fusion** - smashing together light ions in a plasma to make heavier ions, and energy
- **Heavy Ion Fusion**, using beams of heavy ions to heat plasma and make electricity - what we are trying to do
- **Computer simulations of ion beams** - my own work

Thanks for your attention